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November 22, 1996

VIA HAND DELIVERY

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, DC 20554

Re: MM Docket No. 87-268 - Advanced Television Systems

Dear Mr. Caton:

Transmitted herewith, on behalf of Cornell University, are the original and five copies of the Comments of Cornell University in MM Docket No. 87-268.

Please contact me if you have any questions regarding this matter.

Very truly yours,

Paul J. Feldman
Counsel for Cornell University

PJF/jr
Enclosures

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ORIGINAL

BEFORE THE

Federal Communications Commission

WASHINGTON, D.C. 20554

In the Matter of	)	
	)	
Advanced Television Systems	)	
and Their Impact Upon the	)	MM Docket No. 87-268
Existing Television Broadcast	)	
Service	)	

COMMENTS OF CORNELL UNIVERSITY

Cornell University ("Cornell"), by its attorneys, hereby submits its Comments in response to the Sixth Further Notice of Proposed Rule Making, released July 25, 1996, in the above-captioned proceeding ("*Sixth Notice*"). Cornell manages and operates the Arecibo Radio Astronomy Observatory in Arecibo, Puerto Rico (the "Arecibo Observatory") under a Cooperative Agreement with the National Science Foundation ("NSF"). In these Comments, Cornell seeks revision to two proposed digital television ("DTV") allotments (in Arecibo, Puerto Rico and Christiansted, Virgin Islands) in order to protect critical radio astronomy observations.

The Commission has for years, and in many proceedings, recognized the importance of protecting the unique research performed at the Arecibo Observatory and other radio astronomy observatories.[1] Research done at the Arecibo Observatory has been acclaimed world-wide; for example, the 1993 Nobel Prize for physics was

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[1] *See, e.g.,* ET Docket No. 96-2 (Proposed Radio Astronomy Coordination Zone in Puerto Rico) and MM Docket No. 95-17 (Protection of Radio Astronomy Activities on Channel 37).

awarded to Russell Hube and Joseph Taylor for their discovery of a binary pulsar, using the Arecibo Observatory facilities. In addition, measurements of radio spectral line emissions taken at the Arecibo Observatory have identified and characterized the birth sites of stars in our own Galaxy, and the complex distribution and evolution of galaxies in the Universe. Furthermore, in addition to increasing knowledge of the universe, the technique of very-long-baseline interferometry ("VLBI"), developed for cosmic observations, is increasingly producing substantial benefits through use in terrestrial observations, including measurements of global distances (e.g., identification of potential earthquake zones through measurement of fault motion), and through major contributions to navigation, including the tracking of spacecraft. Yet, as passive users of the spectrum, radio astronomers have no control over the character of the signals that they study. Such signals are extremely weak -- typically in the range of one-trillionth of a watt from even the strongest cosmic source. The sensitive radio astronomy receivers needed to pick up such signals are therefore particularly vulnerable to interference from unwanted emissions from users of neighboring bands. In sum, the benefits of radio astronomy performed at the Arecibo Observatory and other observatories, obtained through years of work and millions of dollars of federal investment, must be protected.

In Comments filed in response to the Second Notice of Proposed Rulemaking in this proceeding ("*Second Notice*"), Cornell submitted a "Technical Statement Concerning the Adverse Impact of Advanced Television Allotments on Radio Astronomy Facilities in Puerto Rico and the Virgin Islands", and argued that the

Channels 36, 38, 52, 53 and 54 should not be allotted as proposed in the *Second Notice's* Draft Table of Allotments. A copy of that Technical Statement is attached hereto as Exhibit 1. The principles and calculations made in the Technical Statement are still valid, and are incorporated by reference herein.

Cornell is pleased that Channels 52 through 54 fall outside of the *Sixth Notice*'s DTV "core spectrum" proposal, and that Channel 37 is allocated for use by the radio astronomy service and has not been allocated for DTV services. Unfortunately, however, the Draft Allotment Table in the *Sixth Notice* proposes the allotment of DTV Channels 53 and 38 to locations very close to radio astronomy observatories.[2] As a result, substantial out-of-band interference to VLBI operations at St. Croix (using 608-614 MHz), and to critical spectral line observations of the hydrogen band (1400-1427 MHz)[3] at the Arecibo Observatory, would be likely.

Compounding the problem of out-of-band interference for radio astronomy facilities using Channel 37 is the proposed change of the rules regarding separation of DTV stations, as opposed to NTSC stations. A radio astronomy facility operating on Channel 37 can only be protected by separation distances beyond the upper edge of

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[2] Channel 53 is proposed for Arecibo, Puerto Rico, the location of the Arecibo Observatory. Channel 38 is proposed for Christiansted, Virgin Islands, only 12.9 kilometers from the National Radio Astronomy Observatory at St. Croix.

[3] The 21 centimeter (1420 MHz) emission of atomic hydrogen, and the 1400-1427 MHz band protected on a world-wide basis for observations of Doppler shifts of the hydrogen signal, are in the second harmonic of Channel 53 (704-710 MHz). Spurious emissions from Channel 53 could thus substantially impede observations in what is probably the most important spectral band for radio astronomy. It should be noted that the same problem exists with Channels 52 and 54, but not with Channel 55.

the proposed exclusion zone for adjacent channels, or by specific limits on spectral flux densities. The *Sixth Notice* does not explicitly state the criteria that the Commission would use in the allocation of channels adjacent to Channel 37. Furthermore, in considering the threat of excessive DTV emissions to adjacent band radio astronomy observations, the Commission must take into account the different character of the DTV "spread spectrum" transmission, which allow a higher average signal level in adjacent bands than NTSC transmissions. Therefore, avoidance of nearby adjacent Channels 36 and 38, or their eventual elimination from the DTV Allotment Table in Puerto Rico, are of great importance for future use of Channel 37 by the radio astronomy service.

Accordingly, Cornell urges the Commission to reconsider the following two allotments:

(1) DTV Channel 53 to Arecibo, Puerto Rico.

While both Channel 54 and 53 lie outside the "Core Spectrum" and stations assigned those channels may eventually be moved within the "Core", for many years in the immediate future the Arecibo Observatory faces a serious danger of harmful interference in the L-band, as elaborated in Exhibit 1. Although, in the recent past, the Observatory has enjoyed collaboration with Channel 54, whereby its harmonic level has been kept to 100 dB below the Commission's standards for spurious emission, in view of the imminent completion of the Gregorian Upgrade which will make the Observatory far more sensitive in the L-band,[4] it will be highly detrimental to the

[4] At a cost of $22.8 million, provided by the NSF and the National Aeronautics and Space Administration, the telescope at the Arecibo [note continued next page]

functioning of the Observatory to have Channel 53 (or even Channel 54) broadcast from a distance of only 7 miles. On the other hand, because the harmonics of Channel 55 are outside of the hydrogen band, it does not pose a similar threat, and accordingly, Cornell recommends that if Channel 53 must be allocated in Puerto Rico, that the proposed allotments for Channels 53 and 55 at Arecibo and Fajardo (62 miles away from the Observatory) be interchanged.

(2) DTV Channel 38 to the Virgin Islands or Puerto Rico.

The proposal to allot DTV Channel 38 to Christiansted, Virgin Islands (or anywhere in the Virgin Islands or Puerto Rico) poses a threat of substantial interference to both the Arecibo Observatory and the NRAO Observatory in St. Croix. NRAO's VLBI St. Croix facilities make regular observations at Channel 37, and out-of-band emissions from Channel 38 facilities only 12.9 kilometers away in Christiansted could be particularly disruptive. Similarly, the Arecibo Observatory also makes regular observations on Channel 37, and especially after the recent upgrade, it is particularly vulnerable to out-of-band emmissions from Channel 38. Cornell thus requests that the Commission avoid allotting DTV Channel 38 to Christiansted, or to any other community in the Virgin Islands or Puerto Rico. Duplication of channels used in the western part of Puerto Rico (e.g., Channel 32) could in principle be adopted for Christiansted, allowing continuation of important VLBI observations at this site.

Observatory is being upgraded so that it will be able to make routine observations anywhere from 50 MHz up to 15 GHz and beyond. In combination with reduced system temperatures, the sensitivity of the world's most sensitive radio telescope will be increased by 50 to 500 percent.

It is unfortunate that NTSC Channel 38 was in the past assigned to San Sebastian, only 27 miles from the Arecibo Observatory. A long term goal should be that when the San Sebastian station commences DTV operations on Channel 17, that Channel 38 be removed from the Puerto Rico/Virgin Islands Table of Allotments.

Conclusion

As shown herein and in the attached Technical Statement, the allotment of Channel 38 to Christiansted, Virgin Islands and of Channel 53 to Arecibo, Puerto Rico, will substantially harm critical radio astronomy observations. Accordingly, Cornell requests that the proposed DTV Table of Allotments be revised to eliminate the allotment of these particular channels to these particular communities.

Respectfully submitted,

CORNELL UNIVERSITY

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November 22, 1996

EXHIBIT 1

TECHNICAL STATEMENT CONCERNING THE ADVERSE IMPACT OF ADVANCED TELEVISION ALLOTMENTS ON RADIO ASTRONOMY FACILITIES IN PUERTO RICO AND THE VIRGIN ISLANDS

I. INTRODUCTION

This technical statement has been prepared on behalf of Cornell University by the undersigned in response to the Commission's Second Further Notice of Proposed Rule Making ("Notice") in Mass Media Docket No. 87-268. The Commission seeks comment on principles used to generate its sample table of allotments. As described herein, those principles currently ignore the adverse effects of advanced television ("ATV") allotments on two major radio astronomy facilities -- the Arecibo Observatory at Arecibo, Puerto Rico, and the National Radio Astronomy Observatory ("NRAO") site at St. Croix, Virgin Islands. To avoid harmful interference, ATV channels 36, 38, 52, 53 and 54 must not be allotted to Puerto Rico or St. Croix. This should be an underlying principle as the Commission continues work on the ATV table of allotments.

II. THE ARECIBO OBSERVATORY

The Arecibo Observatory is the world's largest radio telescope. It is located about 17 kilometers south of Arecibo, a city on the north coast of Puerto Rico, and is uniquely identified by the geographic coordinates of 18° 20' 46" north latitude and 66° 45' 11" west longitude. It is part of the National Astronomy and Ionosphere Center ("NAIC"), a federally-owned national research center operated by Cornell University under terms

of a cooperative agreement with the U.S. National Science Foundation ("NSF"). The telescope was constructed from 1960 to 1963 and was extensively upgraded from 1972 to 1974 for operation at shorter wavelengths. A further upgrade of the telescope for higher sensitivity and lower system temperatures is now underway.

The telescope operates 24 hours per day, year around. The Observatory is staffed with 132 persons in Puerto Rico and 12 persons in Ithaca, New York. It is publicly funded with an annual operating budget of $7.5 million supplied by the NSF and supplemented for planetary research by NASA.

The Arecibo Observatory reflector is 1000 feet in diameter, 167 feet deep and covers about 20 acres. The surface consists of 40,000 perforated aluminum panels supported by a network of steel cables strung across a natural sinkhole. The surface has been adjusted to an accuracy of less than 0.1 inch RMS over the entire 20 acres. A 600-ton receiver platform is suspended at 450 feet above the reflector surface with cables from three concrete towers. The platform consists of a supporting triangle and a movable bow-shaped azimuth arm with two suspended carriage (receiver) houses. In one carriage house is the 430 MHz line feed that is mostly used for ionospheric measurements. The second carriage house has six line feeds ranging in frequency from 1000 MHz to 2380 MHz that are used for spectral line radio astronomy and radar astronomy experiments. A new Gregorian subreflector system will replace the second carriage house and will operate from 300 MHz to 10 GHz. This upgrade project has been funded by the NSF and NASA for $22.8 million, and should be finished by Spring, 1994.

Research at Arecibo uses the most sensitive radio receivers in existence. The 21 cm wavelength (1420 MHz) system routinely detects radiation from galaxies with a flux density of 10^{-29} watts per square meter per hertz ($W/(m^2Hz)$). A single snowflake falling to the ground releases far more energy than is collected in a year's worth of observations. The equipment used at Arecibo is so sensitive it could detect the signal from a child's walkie-talkie a million miles away. The research capability of the telescope will increase further with the Gregorian upgrade, which will render the telescope 50 percent more sensitive and dramatically increase the frequency coverage of the telescope.

Basic research in radio astronomy, radar astronomy, and atmospheric science has put a heavy demand on the telescope resulting in an approved research proposal backlog of more than one year. With its powerful transmitters, sensitive receivers and sophisticated data acquisition and analysis equipment, the Observatory plays a leading role as a versatile research instrument in radiophysics.

III. THE ST. CROIX NRAO TELESCOPE

The St. Croix NRAO site is at 17° 45' 31" north latitude and 64° 35' 03" west longitude. It is used in connection with very long baseline interferometry ("VLBI") observations. VLBI observations began in the 1970s and their importance and frequency have increased steadily over the years. During the early development of VLBI there was much emphasis on using the highest practical frequencies to obtain the highest angular resolution. However, with the development of intercontinental baselines, the use of a wide range of frequencies has

become important. Observations of the 608-614 MHz band are being implemented with the Very Long Baseline Array ("VLBA"), which is now the primary VLBI array within North America.

The VLBA is an array of 10 antennas distributed across the U.S. from Hawaii to St. Croix and including the St. Croix NRAO site. Computer processing of data recorded at each of the 10 antennas enables scientists to construct images equivalent in detail to those that would be obtained with a single 8,000 kilometer antenna. Besides the 608-614 MHz band, the St. Croix NRAO facility will conduct observations in other bands, including 1400-1427 MHz.

IV. THE ALLOTMENT OF ATV CHANNELS 52, 53 OR 54 IN PUERTO RICO OR ST. CROIX WILL LEAD TO HARMFUL INTERFERENCE

Because of its high population concentration, Puerto Rico is second only to the northeast U.S. in terms of television station density. As the Notice states, Puerto Rico has more than half of the TV broadcasting channels (34 out of 67 channels) already allotted.[1] The small size of Puerto Rico does not permit frequency reuse, and many existing facilities are extremely short-spaced.

In the Commission's sample ATV table of allotments, ATV channel 53 was allotted to Arecibo, Puerto Rico.[2] While the Commission is not now seeking comments on specific conversion channel allotments in the draft table, the allotment of channel 53 suggests lack of

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[1] Notice at para. 53, n. 56.

[2] Notice, Appendix D, p. D-28.

consideration of radio astronomy protection in ATV allotment and assignment policy. The following discussion demonstrates how ATV stations operating on channels 52, 53 or 54 in Puerto Rico will cause harmful interference to the Arecibo Observatory due to harmonic interference.

Calculations of the field strength of the permitted harmonic radiation from a TV transmitter can be made using the Commission's rules and assuming no intervening terrain shielding. Footnote US74 of 47 CFR 2.106 states:

> In the bands . . . 1400-1427 MHz . . . the radio astronomy service shall be protected from extraband radiation only to the extent that such radiation exceeds the level which would be present if the offending station were operating in compliance with the technical standards or criteria applicable to the service in which it operates.

The second harmonics of channels 52, 53 and 54 fall in the 1400-1427 MHz band.

Section 73.687(e) of the Commission's rules states in part:

> As measured at the output terminals of the transmitter (including harmonic filters, if required) all emissions removed in frequency in excess of 3 MHz above or below the respective channel edge shall be attenuated no less than 60 dB below the visual transmitted power.

Calculations done by the engineering staff at the Observatory show that a 1500 kilowatt ATV station at channel 53 and at a distance of 50 km from Arecibo Observatory would have a broadband second harmonic power flux of about -97.7 dBm at 1414 MHz, calculated at 60 dB

below the fundamental.[3] However, CCIR document 224-7 defines the level of harmful interference in this band as -192 dBm. There is a discrepancy of approximately 94 dB between the harmonic emission levels allowed by the FCC and those considered harmful.[4]

This interference is not simply hypothetical. Today, interfering harmonic emissions in the 1400-1427 MHz band are being experienced at Arecibo Observatory from WCCV-TV, channel 54, Camuy, Puerto Rico. That station has been permitted to increase power to 1500 kilowatts and move to a location south of Arecibo Observatory and within direct line of sight to the Observatory. WCCV-TV has recently begun testing at its new location. Since the commencement of testing, the Observatory has been experiencing severe harmonic interference in the 1400-1427 MHz band -- a band where radio astronomy enjoys primary status.

This "minor change" by a TV station has become a major threat to the Observatory. Cornell University filed a Petition for Extraordinary Relief at the Commission regarding the interference potential from WCCV-TV.[5]

The problems posed by a channel 52, 53 or 54 ATV allotment will be similar to those now caused by the WCCV-TV upgrade. The second harmonic of channels 52 or 53

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[3]1414 MHz is the center frequency of the channel 53 second harmonic. 1500 kilowatts was chosen because it is the same power used under test by existing WCCV-TV, as discussed later in this statement.

[4]The Commission states in the Notice that it is possible that ATV stations will operate at power levels 10 dB less than existing stations (Notice at para. 18, n. 23). As can be seen from these predictions, a 10 dB reduction in interference is insignificant.

[5]Filed January 8, 1992.

would also fall in the 1400-1427 MHz band and, under 47 CFR 73.687(e), be allowed to be approximately 70 dB above what is considered by the CCIR to be harmful interference. Any interference in the 1400-1427 MHz band harms neutral hydrogen studies of the galaxy because the rest frequency of neutral hydrogen is blanketed, reducing the ability of the Observatory to study the structure of the galaxy and other nearby galaxies.

Because of the extreme sensitivity of the Arecibo Observatory, the allocation of ATV channels 52, 53 or 54 would likely cause harmonic interference problems if they were allocated to any city in Puerto Rico. Consequently, channels 52, 53 or 54 should not be used at all in the ATV allotment table for Puerto Rico.[6]

A similar argument can be made concerning the St. Croix NRAO telescope. To avoid harmful interference, ATV allotments on channels 52, 53 or 54 should not be made in St. Croix.

V. THE ALLOTMENT OF ATV CHANNELS 36 OR 38 IN PUERTO RICO OR ST. CROIX WILL LEAD TO HARMFUL INTERFERENCE

Channel 37 has been left unassigned by the FCC to allow radio astronomy observations in this 6 MHz spectral window. This continuum observing band is mostly used for flux measurements and for interferometric observations using unconnected antennas at great distances. The upgraded Arecibo Observatory and the dedicated interferometry antenna at St. Croix will use

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[6]In addition to considerations of harmonic interference, the high fields due to the fundamental signal of nearby terrestrial stations can cause intermodulation in highly sensitive receivers. This can occur regardless of the frequency of transmission.

this band often. However, no protection has been awarded to the radio astronomy observatories for the use of this band with regard to the separation rules customary for broadcasting services; i.e., no adjacent channel protection exists.

A Petition for Rulemaking has been filed by the Committee on Radio Frequencies ("CORF") of the National Academy of Sciences concerning the protection of channel 37.[7] The petition requests the implementation of adjacent channel protection for the telescopes of the two national observatories, NRAO and NAIC, in the same manner that protection is applied to conventional broadcasting stations. The Arecibo Observatory and the St. Croix NRAO telescope have been specifically mentioned in the petition.

To ensure the effective use of the frequency band of channel 37 for scientific observations at Arecibo and St. Croix, it is important that the proposals made in the CORF petition be followed when drafting the ATV allotment table. Specifically, both the Arecibo Observatory and the St. Croix VLBA antenna should be considered as if they were channel 37 facilities and protected under adjacent-channel distance separation standards.

Channels 36 and 38 are now allocated to Bayamon and San Sebastian, Puerto Rico, respectively.[8] In the

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[7]Filed on June 2, 1992, placed on Public Notice October 14, 1992.

[8]WJWN-TV, channel 38, is licensed to San Sebastian, and is 45.1 kilometers from the Arecibo Observatory. WDWL, channel 36, holds a construction permit for operation at Bayamon, and is 68.4 kilometers from the observatory. Under 47 CFR 73.610(c)(1), the

proposed ATV rulemaking, channel 36 has not been assigned in Puerto Rico or the Virgin Islands, but channel 38 has been assigned to Christiansted, St. Croix, Virgin Islands. Using the Christiansted geographic coordinates from the National Atlas, the St. Croix NRAO facility is only 12.9 kilometers from Christiansted. This very short distance will likely result in harmful interference to the NRAO facility.

VI. CONCLUSION

Precluding the allotment of ATV channels 36, 38, 52, 53 and 54 in Puerto Rico and St. Croix is essential for preserving the future of critical radio astronomy activities. Both the Arecibo and St. Croix radio telescopes will be used extensively on those channels. Once interference shuts down part of the spectrum at these facilities, any sensitive observations at the affected frequencies are effectively eliminated. In the case of the Arecibo Observatory, no other telescope in the world can provide equivalent sensitivity.

Accommodation for the needs of the Arecibo Observatory and the St. Croix radio telescope in the ATV allotment table will prevent further interference problems such as those now experienced at Arecibo from WCCV-TV. An allocation of ATV channel 52, 53 or 54 in Puerto Rico will lead to interference even greater than already caused. The ongoing Gregorian Upgrading project at Arecibo Observatory will make the telescope more sensitive and more frequency agile, opening new frequency bands for

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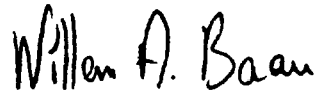
standard UHF-TV adjacent channel distance separation requirement is 87.7 kilometers.

research, and making protection from ATV interference all the more important.

Adjacent channel protection for channel 37 is essential for both the Arecibo Observatory and the St. Croix NRAO site. The channel 37 observing band will continue to be used for interferometric continuum measurements by both Arecibo Observatory and the St. Croix antenna.

The threat of interference from nearby transmitting facilities is an extremely serious issue. Loss of research capabilities at Arecibo due to TV broadcast interference is a permanent loss for the U.S. and the world, because no other telescope can serve as a replacement. Preservation of frequency bands and the suppression of interference are of the highest priority for the future of the Arecibo and St. Croix facilities, and should be a guiding principle in the Commission's further drafting of the ATV table of allotments.



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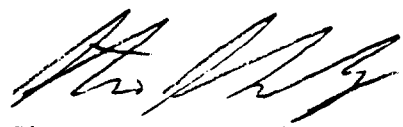

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